Operational considerations related to operating MAN B&W two-stroke engines on distillate fuels

To whom it may concern

Due to the coming environmental legislation on fuel sulphur contents, MAN B&W two-stroke engines will operate on distillate fuels (marine gas oil (MGO) and marine diesel oil (MDO)) in the future. As engine designer, we get many questions related to this.

It must be emphasised that MAN B&W two-stroke engines can operate on fuels fulfilling the ISO8217:2005 specification, including distillate fuels, without making modifications to the engine itself.

This document will go through the prior considerations to operating on low sulphur fuels and will be followed up by a more detailed description, based on experience, in a new paper later this year.

Correlation between fuel sulphur level and cylinder condition
During combustion, sulphuric acid is formed from the fuel sulphur. Part of the sulphuric acid condenses on the cylinder liner causing corrosive attack. The cylinder lube oil contains base with the aim of neutralising the acid.

Some corrosion is beneficial to the cylinder condition as this keeps an open graphite lamella structure of the cylinder liner surface from where the cylinder lubricant can spread. The purpose is therefore not to avoid corrosion but to control corrosion. This is done by adjusting the amount of base, i.e. by either using BN40 cylinder lube oil (instead of BN70 as normal for operation on HFO), by optimising the cylinder oil feed rate to the actual fuel sulphur level or a combination of both.

Over-additivation, i.e. too much base compared to the actual fuel sulphur level, may result in bore polishing (mirror-like surface indicating a closed liner structure) and deposit formation on the piston – both increasing the risk of scuffing significantly.

For high topland engines (high topland pistons are pistons where the topland is significantly higher than the ringland), MAN Diesel recommends to change to a BN40 cylinder oil at minimum feed rate operating for extended periods (typically more than two weeks) on low sulphur fuel in e.g. SECAs (SECA = Sulphur Emission Control Area). This also goes for distillate fuels.

We have reports of older low topland engines operating continuously on low sulphur fuels and with BN70 cylinder oil without problems. In such cases, it is subject to owner decision whether to change to a BN40 cylinder oil.

Please refer to MAN Diesel documents “Operation on Low Sulphur Fuels”, SL385, SL455, SL479 and SL507 for more information and recommendations on cylinder oil feed rate.

Viscosity / lubricity
Low sulphur fuel oils often mean marine gas oil (MGO) or marine diesel oil (MDO) which are also low on viscosity compared to heavy fuel oil. ISO8217:2005 specifies MGO (DMA grade) with a viscosity of min. 1.5 cSt at 40^{0}C. It seems that the ultra low viscosity fuels are not yet common worldwide. However, as the

future holds stricter fuel sulphur requirements and the request of low sulphur marine fuel increases, the viscosity of the offered fuels may also decrease.

Lubricity may be poor for low sulphur distillates for which reason MAN Diesel recommends that the lubricity is tested by an HFRR test (according to ISO12156-1) by an independent laboratory prior to using the fuel.

In order to ensure a satisfactory hydrodynamic oil film between fuel pump plunger and barrel, thereby avoiding fuel pump seizures/sticking, MAN Diesel recommends to keep a fuel oil viscosity at min. 2 cSt measured at the engine inlet. This limit has been used over the years with good results and recent tests indicate that this limit gives the required safety margin against fuel pump seizures.

For MGO, viscosities below 2 cSt may be reached at temperatures above 35°C. As the fuel temperature increases during operation, it is impossible to maintain this low temperature at the engine inlet. In the worst case, a temperature of 60-65^{0}C at the engine inlet can be expected corresponding to a viscosity far below 2.0 cSt. The consequence may be sticking fuel components.

Also most pumps in the external system (supply pumps, circulating pumps, transfer pumps and feed pumps for the centrifuge) already installed in existing vessels need viscosities above 2 cSt to function properly. We recommend that the actual pump maker is contacted for advice.

An MGO with a minimum viscosity of 1.5 cSt at 40^{0}C, requires approximately 22^{0}C to keep the 2 cSt limit:

	Min. viscosity at 40°C	2 cSt is reached at :	3 cSt is reached at :
DMA	1.5 cSt	Appr. 22^{0}C	Appr. 2°C

Please refer to appendix A for guiding temperature/viscosity curves.

One way to ensure a minimum viscosity of 2 cSt is to install a cooler in the system. Figure 1 shows the recommended location to install a cooler.

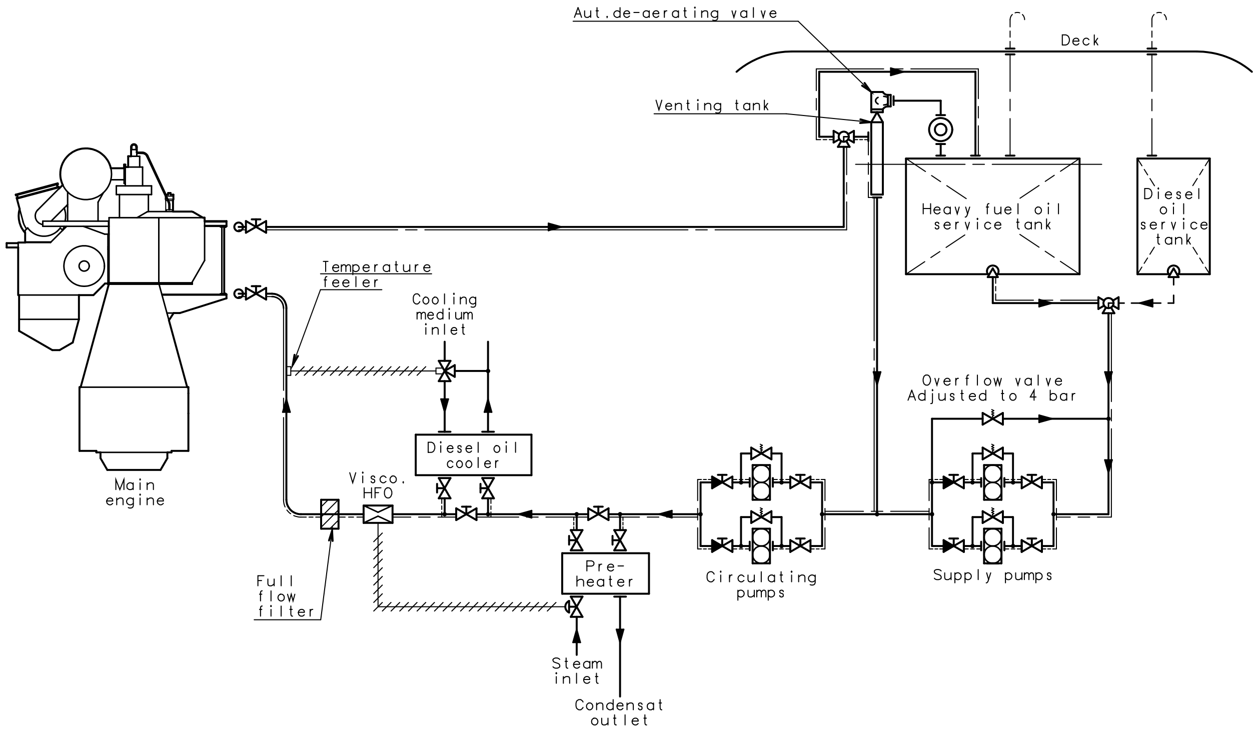


Figure 1: Fuel system (cooler installed after the circulating pumps)

The advantage of installing the cooler just before the engine is that it is possible to optimise the viscosity regulation at the engine inlet. However, the viscosity may drop below 2 cSt at the circulating (and other) pumps in the system.

The cooler can also be installed before the circulating pumps. The advantage in this case is that the viscosity regulation may be optimised for both the engine and the circulating pumps.

It is not advisable to install the cooler just after the engine or after the diesel oil service tank as this will complicate viscosity control at the engine inlet. In case the cooler is installed after the service tank, the supply pumps will have to handle the pressure drop across the cooler which cannot be recommended.

Seawater should not be used for the cooler due to the risk of fuel leaking into the sea water and polluting the ocean.

The following items should be considered before specifying the cooler:

- The flow on the oil side should be the same as the capacity of the fuel oil circulating pump
- The fuel temperature to the cooler depends on the temperature of the fuel in the service tank and the temperature of return oil from the engine
- The temperature of the cooling medium inlet to the cooler depends on the desired fuel temperature to keep a min. viscosity of 2 cSt
- The flow of the cooling medium inlet to the cooler depends on the flow on the oil side and how much the fuel has to be cooled

Heat dissipation for diesel oil cooler:

Engine Type	**7S60MC-C7**
IMO-NOx compliant	Tier 1
Engine Power	15,820 kW
SFOC	170.0 g/kWh
Fuel oil consumption	3.02 m³/h
MGO temperature in service tank	45 °C
MGO temperature return from engine	40 °C
MGO temperature which viscosity is 2 cSt	22 °C
MGO density at 15 °C	890.0kg/m³
Specific heat capacity of MGO	2.0 kJ/kg °C
Capacity of supply pump	4.00 m³/h
Capacity of circulation pump	7.90 m³/h
MGO flow return from engine	4.88 m³/h
MGO cooler heat dissipation	76 kW
MGO flow to cooler	7.90 m³/h
MGO temperature to cooler	42 °C
Cooling medium flow to MGO cooler	
Cooling medium temperature inlet to MGO cooler	18 °C

Table 1: Example of specifying a cooler for the fuel system.

Based on the fuel oils available in the market as of June 2009, a fuel inlet temperature of min. 40^{0}C is expected to be sufficient to achieve 2 cSt at engine inlet. In such case, the central cooling water (max. 36^{0}C) can be used as coolant.

For the lowest viscosity MGOs and MDOs, a cooler may not be enough to sufficiently cool the fuel as the cooling water available onboard is typically LT cooling water (36^{0}C). In such cases, it is recommended to install a so-called ‘Chiller’ which removes heat through vapour-compression or an absorption refrigeration cycle.

A ‘Chiller’ is a machine that removes heat from a liquid via a vapour-compression or an absorption refrigeration cycle. The ‘Chiller’ principle is shown in Figure 2.

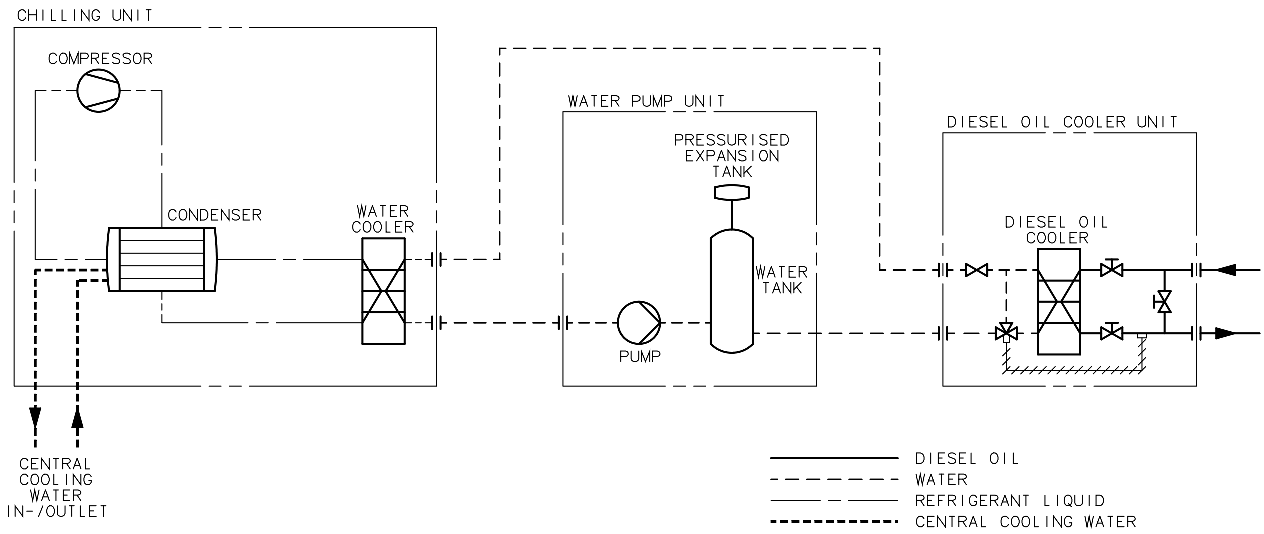


Figure 2: Chiller

Change-over between HFO and MGO/MDO

Reference is made to our general instruction for changing over from HFO to MDO/MGO and back given in our Operation book, plate 705-03 and our paper “Operation on Low Sulphur Fuels, Two-Stroke Engines”.

Prior to the intended change-over from HFO to MGO and vice versa, we recommend that the compatibility of the two fuels is checked – preferably at the bunkering stage. The compatibility can be checked either in an independent laboratory or by using test kits onboard.

Incompatible fuels may lead to filter blocking and extra focus should be on filter operation in case of incompatibility.

Change-over to/from MGO can be somewhat dangerous for the fuel equipment as hot heavy fuel (80^{0}C) is mixed into relatively cold gas/diesel oil. The mixture is not expected to be homogeneous immediately and some temperature/viscosity fluctuations are to be expected. The process therefore needs careful monitoring of temperature and viscosity.

During change-over, the temperature increase/decrease rate should be less than 2^{0}C/min. to protect the fuel equipment from thermal shock (expansion problems) resulting in sticking. A fully automatic change-over function including the fuel cooler control will be beneficial to avoid incidents related to human mistakes.

Tests of different mixing possibilities such as the “Diesel Switch” which contains a special automatic change-over system are presently in progress.

It should be noticed that with operation on MGO/MDO, the wear in the fuel pumps should be monitored by comparing the fuel index for the new engine and during service. At a 10% increase of the fuel index for the same load, the plunger/barrels are considered as worn out and should be replaced.

During service on low viscosity fuel, internal leakages in the fuel equipment will increase and there might be a risk of starting difficulties. An increased start index might be necessary.

Prior to manoeuvring in port it should be tested that the engine is able to start on MGO.

Change-over from HFO to MGO

- Ensure that the temperature of the MGO in the service tank is on an acceptable level regarding the expected viscosity at the engine inlet
- Reduce the engine load
    - The load during this process should be 25-40% to ensure a slow reduction of the temperature
    - The load can, based on experience, be changed to a higher level – up to 75% as described in our Operation book
- Stop steam tracing and steam to pre-heater
- Carry out change-over of fuel when the fuel temperature starts to drop
- Please note that a complete change-over (only MGO in the system) can take several hours depending on the engine load, volume of fuel in the circulating circuit and the system layout

In general, only the viscosirator should control the steam valve for the fuel oil heater. However, observations of the temperature/viscosity must be the factor for manually taking over the control of the steam valve to protect the fuel components.

Two things to be kept under observation during the change-over are:

a) The viscosity must not drop below 2 cSt and not exceed 20 cSt.
b) The rate of temperature change of the fuel inlet to the fuel pumps must not exceed 2°C/minute.

Change-over from MGO to HFO

The mixing of the hot heavy fuel (80 to 90°C) into relatively cold gas oil can be somewhat difficult as the mixture is not expected to be homogeneous immediately and some temperature/viscosity fluctuations are to be expected.

- Ensure that the temperature of the heavy oil in the service tank is about 80 deg.
- Reduce the engine load
    - The load during this process should be 25-40% to ensure a slow heat-up of the system from max. 35^{0}C for the MGO to normal heavy fuel service temperature (up to 150°C)
    - This load can, based on experience, be changed to a higher level – up to 75% as described in our Operation book
- Start changing over the fuel
- Start steam tracing when the viscosity reaches 5 cSt.

In general, only the viscosirator should control the steam valve for the fuel oil heater. However, observations of the temperature/viscosity must be the factor for manually take over the control of the steam valve to protect the fuel components!

Two things to be kept under observation during this change-over are:

a) The viscosity must not drop below 2 cSt and not exceed 20 cSt
b) The rate of temperature change of the fuel inlet to the fuel pumps must not exceed 2°C/minute.

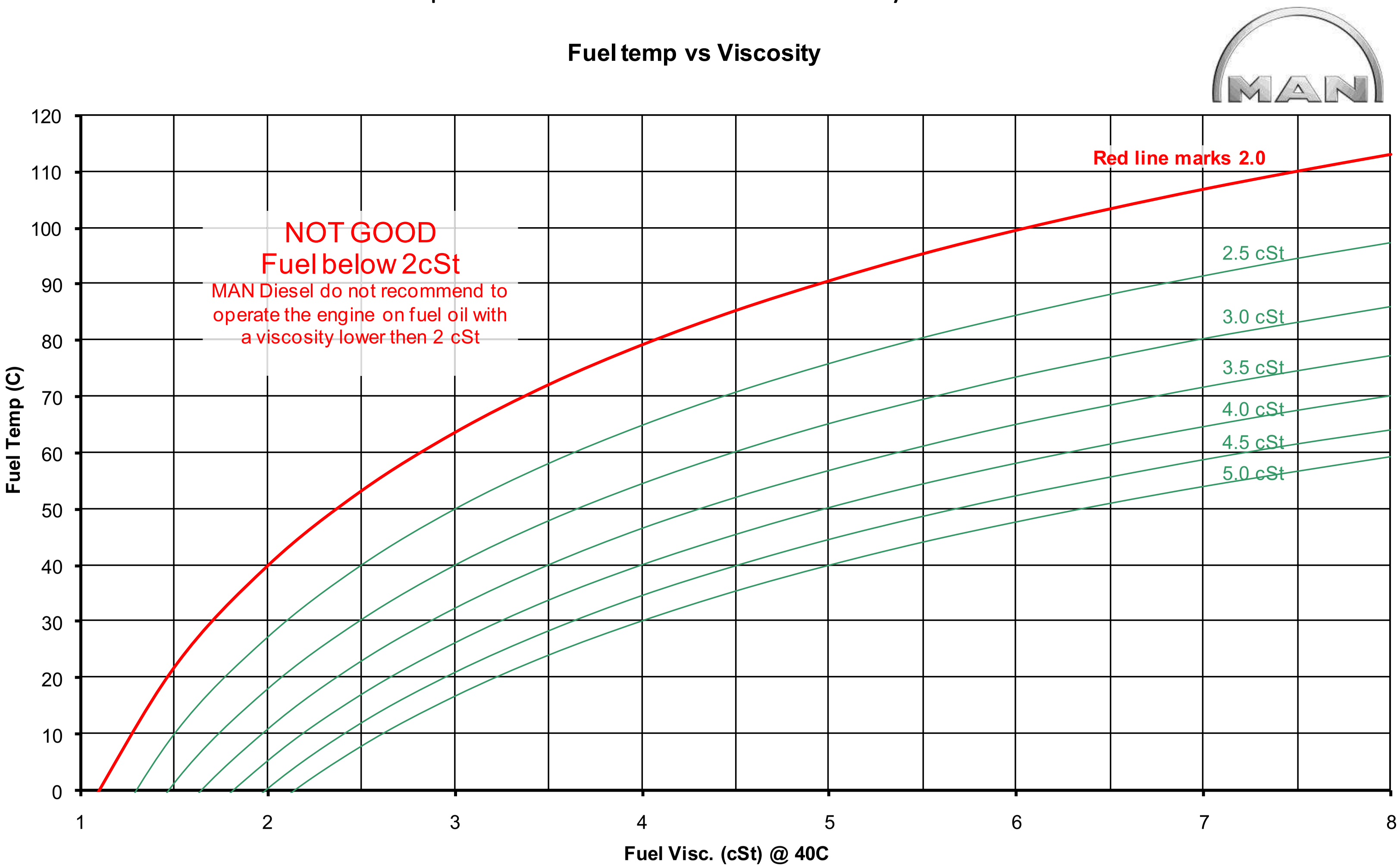
Final remarks

This document is intended as a guideline on how to handle MAN B&W two-stroke operation on distillate fuels. A more detailed paper on the topic will be issued later this year.

Please contact our PrimeServ division regarding more information on installation of coolers/chillers.

Appendix A

Temperature of MGO to ensure viscosity below recommended 2 cSt



The horizontal axis shows the bunkered fuel viscosity in cSt at 40^{0}C (should be informed in the bunker analysis report). If the temperature of the MGO is below the red curve at engine inlet, the viscosity is above 2 cSt.

Example: MGO with viscosity of 3 cSt at 40^{0}C must have a temperature below 63^{0}C at engine inlet to ensure a viscosity above 2 cSt.
Example: MGO with a viscosity of 5 cSt at 40^{0}C is entering the engine at 50^{0}C. The green curves show that the fuel enters the engine at approximately 4.0 cSt.